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Bycatch susceptibility in pelagic longline fisheries: Are albatrosses affected by the diving behavior of medium-sized petrels?

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Bycatch susceptibility in pelagic longline fisheries: Are albatrosses affected by the diving behavior of medium-sized petrels?

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Abstract

Species of petrels and shearwaters with high diving ability could facilitate the catch of albatrosses in pelagic longline, because they retrieve bait to the surface from depths where albatrosses cannot reach. In areas with high density of petrels and shearwaters, these species could indirectly increase the bycatch susceptibility of albatrosses. This scenario occurs in the southwest Atlantic. This paper evaluates the extent to which diving species (i.e. *Procellaria aequinoctialis*, *Procellaria conspicillata* and *Puffinus gravis*) increase the susceptibility of albatross to bycatch in pelagic longline. In 48 sets attacks on baits were quantified (mean c.a. 190 per set). There were 384 attacks on baits, of which 260 were attacked by a single individual and 124 by more than one (i.e. multiple attacks). Multiple attacks were the largest source of bycatch of albatrosses (at least 24 of 31). Combined, the petrels increased by 56% the albatross' access to baits during multiple attacks and it is estimated that 75% of cases, this occurs because the petrels dive after the bait and return to the surface. The diving petrels indirectly increased by 55% the global catch of albatross. This work shows that there are inter-specific effects affecting the likelihood of bycatch and highlight the importance of observations of attacks on bait during the setting as a unique source of information for the conservation of these species.

Introduction

Incidental catch in pelagic longline fisheries is one of the main conservation problems facing seabirds, affecting Procellariiformes (e.g. albatross and petrels) to a greater extent than any other order in this group (Gales 1998, Brothers et al. 1999a). In the Southern Hemisphere, principally in the subtropical and temperate regions, the impact of these fisheries on albatross (Diomedidae) is relatively greater than in other regions of the globe (Brothers 1991, Petersen et al. 2009, Jiménez et al. 2009) as they coincide with the range of distribution of 18 of the 22 existing species in this family (Onley & Scofield 2007).

Various operational and environmental variables (e.g. time of longline setting, season of the year, areas of fishing, lunar phases, among others) could influence the incidental catch of albatross and petrels in pelagic longlines (Brothers 1999a, 1999b, Jiménez et al. 2009, Jiménez et al. 2010). In particular, the configuration of the fishing gear, the type and state of the bait, and the handling of the longline setting affect the rate at which the hooks sink (Robertson et al. 2010a, 2010b), which has a large potential effect on the catch of seabirds. At the same time, other factors such as the abundance of species in different areas, the relative abundance in an area, and the species's method of feeding influence incidental catch (Brothers 1991, Bull et al. 2007).

Each species has a different susceptibility to mortality from interaction with the fishing gear. Incidental catch in pelagic longline fisheries occurs due to the birds feeding on waste, viscera and bait released by the boats. This leads to some birds becoming caught in the hooks or tangled in the lines, primarily during the setting of the longline, while attempting to feed on

the bait, and dying when they sink with the fishing gear. However, feeding methods, morphological restrictions (e.g. the relationship between the beak size and the bait or hook), and the behavior of different species influence incidental catch (Brothers 1991, Bull et al. 2007). The relatively slow rate of sinking of the hooks, compared to demersal longline fishing, allows the birds to more easily take the bait from the surface, dive for it, or even return the bait to the surface while still in the hooks, and hold onto it for several seconds. Consequently, the species that have the greatest probability of being caught while the hooks sink are the species with the greatest ability to dive, and those with larger beaks allowing them to feed on larger items, such as the baits. However, as these species are not isolated but rather form an assemblage that competes for waste and bait, some species gain a greater advantage than is expected from their greater abundance. When a group of species are present during the setting, the most aggressive compete more successfully for the bait. Aggression is related to body size in these birds. In turn the diving species, such as some petrels and shearwaters, can facilitate the bycatch of albatross by returning bait to the surface from depths which the latter cannot reach (Brothers 1991, Jiménez et al. under review).

The susceptibility of a population, considered as a measure of the potential impact of a fishery is often estimated based on four attributes (availability, encounterability, selectivity, and post-capture mortality; Hobday et al. 2011). This paper examines access to the bait as an attribute of the bycatch susceptibility (i.e. encounterability) of seabird in pelagic longline fishing. We intend to determine whether diving species (i.e. petrels and shearwaters) affect the vulnerability of the albatross to incidental catch in pelagic longlines. Albatross have a greater advantage in interspecific competition interactions with petrels and shearwaters. Brothers (1991) suggested that in areas of high density of highly effective diving species (e.g. shearwaters), they may play an important role in significantly increasing the vulnerability of albatross species. This scenario occurs in the southwest Atlantic, where petrels such as *Procellaria aequinoctialis* and *Procellaria conspicillata*, and shearwaters such as *Puffinus gravis* are abundant and are frequently associated with the fishery, diving with high frequency in search of bait, viscera and waste (Jiménez et al. under review). Consequently this paper evaluates the magnitude by which diving species increase the susceptibility of albatross to incidental catch in pelagic longlines. Secondly, we evaluate differences in access to bait allowing us to understand the higher levels of mortality in *P. aequinoctialis* compared to its sister species *P. conspicillata* reported in the southwest Atlantic (Bugoni et al. 2008, Jiménez et al. 2010).

MATERIALS AND METHODS

Fishery and study area

This research was carried out on Uruguayan boats using pelagic longlines. These boats direct their activities towards the catch of swordfish (*Xiphias gladius*), tuna (*Thunnus albacares*, *T. obesus* y *T. alalunga*), and pelagic sharks (principally *Prionace glauca*) since 1981 in a wide region of the southwest Atlantic Ocean. During the last decade the fleet has operated principally between 20°-40°S and 20°-55°W (Domingo et al. 2005, Forselledo et al. 2008, Jiménez et al. 2009, 2010, Pons et al. 2010) deploying nearly 32 million hooks through 2010 (DINARA unpublished). The main fishing gear used consists of the American-style longline (Domingo et al. 2005, Jiménez et al. 2009). The area of study corresponds to the continental slope (between isobath 100 and 200 m) and deep waters (starting at 3000 m) of Uruguay. The longline is set over the vessel's stern, usually after sunset and completed

before midnight. Night setting is practiced mainly as a fishing strategy, and it has a mitigating effect on seabird bycatch (Jiménez et al. 2009a). However, between spring and fall, sets beginning in the daylight hours before nightfall are more frequent (Jiménez et al. 2010). The hooks are set at intervals from 9 to 14 s and a speed of 6 to 9.5 knots. The main bait used is squid (*Illex argentinus*) and less frequently mackerel (*Scomber* spp, *Trachurus* spp.)

The main oceanographic characteristic of this zone is the occurrence of the Brazil/Malvinas Confluence (BMC) formed by the meeting of the Brazilian current and the Falkland Island current (Seeliger et al. 1998, Ortega & Martínez 2007).

Observations of bait attacks

Quantitative observations of seabird attacks on baits were carried out during 12 fishing voyages that took place between 2005 and 2010. Eight commercial fishing voyages took place in 5 boats of the Uruguayan pelagic longline fleet and four in a research vessel during campaigns to assess large pelagic fish. The observations were carried out on 48 diurnal sets in the absence of mitigation measures. No observations were made during high winds (i.e. > force 5: Beaufort scale) or rain. These were temporally distributed in the following way: February (2), May (5) and December (10) 2005; March (4), October-November (5) and December (3) 2006; February 2007 (2); November (1) 2008; May (6) and August (5) 2009; and October (5) 2010.

During the observations the average speed was 7.7 knots (range 7 to 9 knots) and the average interval between hooks was 12 s (range 10 to 14 s), estimating an average distance of 47 m between hooks. Therefore, we considered the distance between hooks in ~ 50m. During the three trips of 2005 hooks were baited with mackerel and in the remaining trips with squid. Preliminary data for 2010 showed that the baited hooks (n = 34) reached an average depth of 2 m, 5 m and 10 m to 14 s, 25 s and 50 s of entering the water, respectively (Jiménez et al. unpublished data).

Each time that a baited hook was set to the water this was observed, using as a reference the snap that connected it to the mother line, at a maximum distance of approximately 150 m from the stern of the boat. We identified an “intent to consume or primary attack on the bait” when a bird descended over the bait attached to a hook or submerged itself following the bait after the hook had sunk (independently of contact and of the outcome). During the phase of the bait sinking, some prospecting birds descend and search along the mother line. In order to exclude these birds, it was not considered as an intent to consume bait when they descended and/or dove outside the immediate proximity of the hooks and/or not in the direction of the bait.

Each time that a bird descended over the baited hook, at the moment when it sank in the water, we registered with the aid of binoculars the species, the distance from the stern of the boat, if contact with the bait was observed or not, and the mode of attacking the bait: if the bird descended and attempted to take it at the surface (i.e. surface attack) or if the bird dove in order to try to take it (i.e. diving attack). We recorded four types of possible result: successful (the bird stole the bait, totally or partially), unsuccessful (the bird was unable to steal the bait), indeterminate, or capture (modified from Brothers 1991). The distance from the stern was measured in two categories: distance between 2 hooks (approximately ≤50 m) or greater than this distance. To determine the first distance we used the reference of the snap. A hook is located at this distance from the moment it is released into the water until a new hook is set, at which point it is at the second distance. In some cases (see Results), we

were not able to record all the descriptive variables for the attack (distance, contact and mode). However, there is no reason to think that the unrecorded fraction for each attribute has a distribution different to the recorded data.

When more than one bird tried to attack the same bait this was defined as a multiple attack, and the order of the species attacking the bait was recorded. The subsequent attacks after the first one were categorized as secondary. In these cases we paid attention to the species and number of individuals of each species that attacked, taking account of order. After quantifying the above-mentioned aspects for a primary attack, if a secondary attack was observed, we recorded the species and the number of individuals. If another new species arrived later, we recorded the identity and number of individuals, and the record continued until the last species was observed to attack. However, during multiple attacks it proved difficult (and inappropriate in conditions of high abundance) to keep track of the number of individuals of each secondary species. In the first place, when more than one bird of each species was observed interacting with the bait, it was difficult to identify individuals and avoid repetitions. In the second place, when many birds interacted over the bait, the count of individuals required a long time. However, access to the bait by a new species was easier to record (see Boggs 2001 for antecedents for this approximation), because of which we prioritized recording the order in which species accessed the bait. For this reason the absolute number of individuals per secondary species was not considered in this analysis. For multiple attacks we recorded the result of the interaction (according to the four possibilities described above) only for the last species observed attacking the bait. All previous attempts were considered unsuccessful.

When the abundance of birds associated with the boat is high, the rate of attack on baits can increase, leaving little time between attacks, and with some baits attacked simultaneously. This limits the time available to record the data on a form, leading to a potential loss of observed attacks during data registration. To reduce this bias during the trips on the research vessel we used two strategies: on a trip where two observers were present, one observed and the other took notes on a form. On other trips we used a digital recorder to maintain continual visual contact with the area where the birds interacted with the hooks, from which we extracted data afterwards.

Before beginning observations we counted the birds, recording the number of individuals present per species. The counts were taken from the stern of the boat over an area approximately 200 m x 400 m (200 m from the stern and 200 m to port and starboard, respectively) and had a maximum duration of 10 minutes when necessary. Since there are 14 principal species that forage and interact over waste in this fishery (Jiménez et al. under review), in order to analyze the abundance of birds we excluded rare species and species that rarely interact with the boats.

During the hauling of the longline we recorded the incidental catch of birds in 100% of the hooks observed during the setting. The caught birds were identified to the species level and sexed, age was classified as immature (including juvenile) or adult based on the coloration of the beak (as well as plumage and the state of the gonads) and we recorded whether they were caught by getting caught on a hook (noting the location) or tangled in the line.

Data analysis

The rate of attack on bait was defined by the number of baits that presented at least one primary attack for each 100 observed hooks (i.e. number of baits attacked/100 hooks). The

rate of multiple attacks was defined as the number of attacks that included at least one secondary attack for each 100 observed hooks. The relative frequency (%FR) of primary and secondary attacks by a species corresponds to the number of primary and secondary attacks that it realized as a percentage of the total number of attacked baits and of the total number of multiple attacks, respectively.

In order to validate the birds classified as caught or to determine the outcome for attacks classified as indeterminate, we used the information on caught seabirds obtained during the hauling. The correlations between number of caught birds and the abundance and the rates of attacks were evaluated using nonparametric statistics in the form of the Spearman correlation. Using the Chi squared (χ^2) test we evaluated differences between proportions for attacks by birds in general and by the principal species that carried out attacks. We constructed 2x2 contingency tables to compare with the Chi square test differences between each species of *Procellaria*. Significance was set at $p < 0.01$. All the average values are presented with \pm a standard deviation.

RESULTS

In total we observed 8960 hooks during 48 fishing sets (median 187 ± 122 hooks per set). At least 24 species of seabirds were present during the observations, including all the principal species that make use of the resources provided by this fishery (i.e. waste, viscera and bait) in the area of study and/or that have been recorded incidentally caught in the fleet (Table 1). We registered attacks on 384 baits, of which 260 consisted only of primary attacks and 124 were multiple attacks. The rate of attack on baits (including at least a primary attack) was 4.32 baits/100 hooks observed, while the rate of multiple attacks was 1.38 attacks/100 hooks. A total of 12 taxa attempted to eat the bait (Table 2). With the exception of the albatross *Diomedea epomophora* and *Diomedea sanfordi*, all the species participated in primary attacks. Nine taxa were observed to participate in secondary attacks during multiple attacks (Table 2).

Of the four possible results for primary attacks, we classified 27 as successful (partial or total robbery of the bait), 58 as indeterminate, 289 as unsuccessful and 10 as resulting in catch of the bird (Table 2). Two successful attacks (with partial robbery of the bait), and 122 unsuccessful attacks led to multiple attacks ($n = 124$). In many cases the multiple attacks involved the interaction of more than one secondary species (1.38 ± 0.62 species per multiple attack), resulting in a total of 171 interactions by secondary species (not including the absolute number of individuals that attacked the bait in secondary attacks, see Methods). Based on the last species that interacted with the bait, the 124 multiple attacks were classified as 18 successful attacks, 23 unsuccessful, 70 indeterminate and 13 resulting in capture of the bird.

The attacks classified as capture or indeterminate were verified during the hauling of the fishing gear. Of the 384 baits where attacks were recorded, 23 of these resulted in the potential catch of a bird (see above), 17 of which were confirmed during the hauling of the longline (5 primary attacks and 12 secondary attacks). The birds were recorded hooked on the hooks by their beaks, esophagus, wings and feet. In two of the secondary attacks resulting in capture we recorded two albatross caught in the same branch line (one caught on the hook and the other tangled in the monofilament). In turn, another 13 birds were recorded during the hauling in the observed hooks. The capture of eight of these birds was attributed to secondary attacks with indeterminate results, with two of these birds caught in the same branch line. However, the attacks of the remaining five birds were not observed

(Table 2). Two of these birds were caught in the same line, one with the hook in the esophagus and the other tangled in the monofilament. The remaining birds were hooked in the interdigital membrane of the foot, by the wing and in the back, on three different hooks. The composition of sexes and ages of all caught birds are shown in Table 3.

The number of birds caught was correlated with the abundance of seabirds (Spearman $R = 0.38$, $p < 0.01$, $n=48$), with the rate of primary attacks (Spearman $R = 0.53$, $p < 0.01$, $n=48$) and with the rate of multiple attacks (Spearman $R = 0.46$, $p < 0.01$, $n=48$).

Characterization of primary attacks

The principal species that engaged in primary attacks were *Thalassarche melanophrys* (44.8%), *P. aequinoctialis* (17.4%), *P. conspicillata* (12.5%) and *P. gravis* (13.0%). Less frequent attackers were *Thalassarche chlororhynchos* (3.9%) and *Thalassarche steadi* (2.6%). The other species engaged in primary attacks less with a frequency of less than 1%. We observed a positive correlation between the frequency of primary attacks carried out by each species and their average abundance (Spearman $R = 0.76$, $p < 0.01$, $n=12$ taxa).

For 299 of the primary attacks (77.9%) we were able to record the distance from the stern at which they were carried out. Of these attacks, we observed that the majority (i.e. 67.6%, $\chi^2 = 36.9$, $p < 0.01$, $gl=1$) were carried out at a distance ≤ 50 m from the stern of the boat, compared to those initiated at a greater distance (i.e. 32.4%). In 335 primary attacks (87.2%) we observed whether the baits were attacked from the surface or whether the bird dove after them as they sank. The majority (58.2%, $\chi^2 = 9.03$, $p < 0.01$, $gl=1$) of these attempts were by diving, while 41.8% were from the surface. In 267 primary attacks (i.e. 69.5%) we recorded if contact was observed with the bait, confirming contact in the majority of cases (73.8%, $\chi^2 = 60.41$, $p < 0.01$, $gl=1$). For the other 70 attacks where contact was not observed, many of these were attacks by diving after the bait (43 attacks) while 25 were from the surface and two were not recorded.

For *T. melanophrys*, *P. conspicillata* and *P. gravis* we determined that the majority of the primary attacks were initiated from less than 50 m from the stern (Fig. 1 A). However, for *P. aequinoctialis* we did not observe significant differences between the proportion of attacks carried out in the first 50 m and further distances (Fig. 1 A). When we compared *P. aequinoctialis* and *P. conspicillata*, the observed differences in the distance at which the bait was attacked were significant ($\chi^2 = 7.35$, $p < 0.01$, $gl=1$). We did not observe differences in the proportion of attacks from the surface or by diving realized by *T. melanophrys* (Fig. 1B). The majority of primary attacks by *P. aequinoctialis*, *P. conspicillata* and *P. gravis* were by diving, although this was not statistically significant for the last species possibly due to the sample size (Fig. 1B). The comparison between *Procellaria* species did not show significant differences with respect to the frequency of diving attacks.

Multiple attacks

In the secondary interactions over bait we observed individuals competing intra-specifically as well as individuals that displaced other species through interference competition. In some cases smaller species accessed the bait after a larger species was unsuccessful in obtaining it. However, in the majority of multiple attacks in which more than one species was involved we observed that larger birds displaced smaller birds. We observed that the relative frequency of secondary attacks increased (with respect to primary attacks) in all species of

albatross and in *Macronectes* spp., while it decreased in *P. aequinoctialis*, *P. conspicillata* y *P. gravis* (Table 2).

Of the 124 multiple attacks observed, 73 (58.9%) were initiated by a primary attack by an albatross species: 67 attacks by *T. melanophrys*, 4 by *T. chlororhynchos* and 2 by *T. steadi*. The remaining 41.1% (51 attacks) of the multiple attacks were initiated by *P. aequinoctialis* (24 attacks), *P. conspicillata* (10 attacks), *Procellaria* spp (8 attacks by both species without discrimination), *P. gravis* (7 attacks) and *Macronectes* spp (2 attacks). Of the 49 multiple attacks initiated by diving petrels and shearwaters, 41 resulted in secondary attacks by at least one species of albatross. Consequently, these species of petrels increased by 56.2% the access of albatross during multiple attacks, with respect to those initiated by a species of albatross ($n = 73$). In the absence of petrels, at least one species of albatross participated in the attack on 203 baits (of 384 baits). The 41 primary attacks by petrels and shearwaters that resulted in secondary attacks by at least one species of albatross increased by 20% the global access of albatross to the bait.

For the primary attacks by petrels and shearwaters that resulted in secondary attacks by albatross, we observed that a majority of them (75.7%; $\chi^2 = 9.76$, $p < 0.01$, $gl=1$) were initiated by diving by one of these species (diving: 28, surface: 9 and unrecorded: 4).

The primary attacks by diving petrels were indirectly responsible for the catch during secondary attacks of 11 albatross (one *Diomedea exulans*, nine *T. melanophrys* and one *T. steadi*). Of the other 20 captured albatross, 16 were caught during attacks not involving petrels, while for the other four it was not possible to determine (see above). Consequently, the diving petrels increased by at least 55% the global catch of albatross.

DISCUSSION

To our knowledge, this is the first work showing that medium sized petrels, with a strong ability to dive, increase in an important way the access to bait, and indirectly, the incidental bycatch of albatross. Multiple attacks were the largest source of incidental catch of albatross (24 of 27 albatross whose attacks were observed). The mode of capture of birds whose attacks were not observed shows that at least two of them (in the same branch line) were also caught in a multiple attack. These petrels, combined, increased by 56% the access of albatross to bait during multiple attacks, with approximately 75% of these cases occurring due to petrels diving after bait and returning it to the surface. In the remaining cases, these species contributed to locating bait on the surface so that other birds could later obtain the bait secondarily.

These results have implications for the conservation of seabirds affected by pelagic longline fisheries. In the southwest Atlantic, the majority of birds caught by pelagic longline fisheries targeting *X. gladius* (and other large pelagic fish) are albatross (Bugoni et al. 2008, Jiménez et al. 2009, 2010), primarily *T. melanophrys*. From the results of this study we deduce that mitigation measures that intend to reduce the access of albatross to bait (i.e. by increasing the rate of sinking of the fishing gear), should also consider the efficiency of also reducing the access of petrels with high diving ability which frequently interact with the bait.

It is important to highlight that the majority of attacks (i.e. 67.6%) were initiated at a distance from the boat of ≤ 50 m. This result is similar to that previously reported (i.e. 62% of attacks at less than 50 m) for pelagic longliners targeting tuna in Australian and adjacent waters (Brothers 1991). In that fishery the use of a tori line reduced the rate of attacks from 1.8 to 0.02 attacks/ 100 hooks in the first 50 m from the stern of the boat (Brothers 1991). The use

of a mitigation measure that impedes the access of birds, at a minimum over this critical distance from the boat, might greatly reduce the bycatch of seabirds in pelagic longline fisheries. However, seabirds were also observed attacking baits farther away. In particular it must be kept in mind that during this study we observed that *P. aequinoctialis* continues attacking bait with a similar frequency at a distance more than 50 m from the boat. Consequently, this species, and primarily the albatross species through secondary attacks (and primary attacks), are still vulnerable at a distance of greater than 50 m from the boat. The application of measures that permit a more rapid rate of sinking of the fishing gear, such that at this distance from the boat the baited hooks sink to a depth greater than that to which petrels dive, could be very useful to optimize the effectiveness of other measures that protect the critical distance mentioned (e.g. tori lines). This requires more research on the efficiency of tori lines in reducing the catch of seabirds and on their application in these fisheries, as well as the development of methods that increase the rate of sinking of the hooks.

Differences between white-chinned and spectacled petrels

The observations took place in the most critical zone of interaction with seabirds of this fishery, in daylight hours, being the period when most birds are caught (Jiménez et al. 2009, unpublished data). Night setting (primarily in less luminous phases of the moon) significantly reduces the bycatch of seabirds (Jiménez et al. 2009). However, both *P. aequinoctialis* and *P. conspicillata* are active during the day and the night (Weimerskirch et al. 2000, Phillips et al. 2006, Bugoni et al. 2009, Mackley et al. 2011) suggesting that they are susceptible to capture during both periods. In this research we observed that although both species obtain bait by diving (at similar rates), *P. aequinoctialis* is also able to do so with the same frequency farther from the boat when the hooks are at a greater depth. The maximum diving depth of this species is 12 m (Huin 1994), and there are no reports for *P. conspicillata*. Comparative studies over the diving ability and detection of its prey could be useful to understand the susceptibility to differential bycatch observed between these sister species. Principally during diurnal sets, albatross could cause an indirect effect on the susceptibility of the petrels, through competitive pressure. In a scenario of high albatross abundance, the petrels should ingest the bait rapidly, before losing them, which might result in a higher rate of getting hooked. Particularly for *P. aequinoctialis*, which is a species characteristic of an assemblage with a greater abundance of albatross, dominated by *T. melanophrys* (Jiménez et al. under review), this could have a greater effect on its catchability with respect to *P. conspicillata*. The latter occurs mainly during the summer, when is notoriously the most abundant of the assembly (Jiménez et al. under review). The impossibility of sampling during the night, when greater proportion of the fishing set take place, did not allow us to obtain a more general understanding of the rates of attack, particularly of these species. The ability to feed at night would reduce the interspecific competition pressure to reach the bait caused by albatross in this fishery, although whether this would differentially affect the rate of access to bait by both species of petrel is unclear.

Considerations on the bait attacks

The captured birds whose attacks were not recorded show that some proportion of attacks could not be observed using our methodology. In the majority of secondary attacks with an indeterminate outcome, the birds continued to interact beyond the sampled distance. Consequently, it is possible that the unobserved captures correspond to secondary attacks far from the boat. The presence of two observers or the use of a digital recorder on the

research boat optimized the time available to record data, generating a lower potential loss of information.

Despite these potential biases, the observations in daylight hours allow us to examine in detail how the birds accessed the bait and to obtain information valuable to the conservation of these birds. The rate of attacks on the bait can be used as a proxy for the incidental catch of birds, as these are positively correlated. These rates can be used for the evaluation of mitigation measures, through experiments quantifying the effectiveness of a device or modification to the fishing gear, compared to a control. As incidental bycatch is rare (the majority of sets are dominated by zeros), the use of attack rates can reduce time and cost to determine the effectiveness of a potential mitigation method. At the same time, recording the order in which different species access the bait (i.e. considering secondary attacks) could increase our understanding of why some species are captured which have a low probability of access bait under standard operating conditions or even with the application of mitigation methods. This could lead to the identification of weak points of mitigation methods and strategies to improve them.

Recently, based on observed bycatch of birds during the setting and those found during the hauling, it was suggested that nearly half of the captured birds are not brought on board during hauling in pelagic longline fisheries (Brothers et al. 2010). In our case, six (26%) of the 23 attacks classified as resulting in capture during the setting were not confirmed during hauling. Birds were also captured whose attacks were not observed. Three caught birds became disattached from the fishing gear when they were hauled (one *D. exulans* and two *T. melanophrys*), suggesting that it is possible that a proportion of the bycatch was not observed during hauling. However we found it difficult to confirm capture during setting and it is very possible that some birds recorded as captured were not. If they were captured, we cannot be sure that they did not escape due to our limited window of observation (less than 40 seconds from the liberation of the hook from the boat). More research is necessary on this point, in order to determine if mortality is underestimated in this fishery and by what magnitude. So far we consider that the most reliable data on incidental mortality comes from birds observed during hauling.

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Table 1. Abundance of seabirds observed (number of individuals) previous to observations of attacks on the bait in pelagic longiners on the Uruguayan continental slope. The species were grouped into species with high or low association with discards and bait in agreement with Jiménez et al. (in review).

Species		Code	Mean	SD	Min.	Max.	Individuals
Forage on discards and baits							
Wandering & Tristan albatrosses	<i>Diomedea exulans</i> y <i>D. dabbenena</i>	DEX	0.46	0.97	0	4	22
Southern Royal albatross	<i>Diomedea epomophora</i>	DEP	0.33	1.52	0	10	16
Northern Royal albatross	<i>Diomedea sanfordi</i>	DSA	0.17	0.52	0	3	8
White-capped albatross	<i>Thalassarche steadi</i>	TST	1.02	3.71	0	25	49
Black-browed albatross	<i>Thalassarche melanophrys</i>	TME	9.06	19.56	0	70	435
Atlantic yellow-nosed albatross	<i>Thalassarche chlororhynchos</i>	TCH	2.44	3.65	0	15	117
Sooty albatross*	<i>Phoebastria fusca</i>	PHF	0.02	0.14	0	1	1
Northern & Southern giant petrels	<i>Macronectes halli</i> y <i>M. giganteus</i>	MAC	3.88	19.52	0	135	186
White-chinned petrel	<i>Procellaria aequinoctialis</i>	PAQ	5.13	5.77	0	20	246
Spectacled petrel	<i>Procellaria conspicillata</i>	PCO	2.63	3.72	0	15	126
Cape petrel	<i>Daption capense</i>	DCA	2.5	4.79	0	20	120
Southern fulmar	<i>Fulmarus glacialisoides</i>	FGL	0.25	0.67	0	2	12
Great shearwater	<i>Puffinus gravis</i>	PUG	2.9	5.48	0	30	139
Low association with discards							
Grey petrel	<i>Procellaria cinerea</i>	PCI	0.02	0.14	0	1	1
Atlantic petrel	<i>Pterodroma incerta</i>	PIN	1.38	2.29	0	13	66
Cory's shearwater	<i>Calonectris diomedea</i>	CDI	0.08	0.28	0	1	4
Manx shearwater	<i>Puffinus puffinus</i>	PPU	0.06	0.32	0	2	3
Wilson storm petrel	<i>Oceanites oceanicus</i>	OOC	1.56	3.76	0	20	75
Black-bellied storm petrels	<i>Fregetta tropica</i>	FTR	0.02	0.14	0	1	1
Skuas	<i>Catharacta</i> spp	CHA	0.06	0.32	0	2	3
Parasitic jaegers	<i>Stercorarius parasiticus</i>	SPA	0.04	0.2	0	1	2
Pomarine jaeger	<i>Stercorarius pomarinus</i>	SPO	0.02	0.14	0	1	1

* Included in species with high association because there is evidence of incidental bycatch.

Table 2. Attacks by seabirds on bait during 48 sets (mean 187 ± 122 baits per set) in pelagic longliners on the Uruguayan continental slope. Shown, the number of primary and secondary attacks (of 124 multiple attacks) and their respective relative frequencies (%), results and catches (those validated in the hauling in parentheses). We show the number of catches that occurred in observed and unobserved attacks. When two birds occurred in the same line a + appears.

Species*	Ataques primarios						Ataques secundarios						Capturas		
	n	FR %	Indet.	Exitoso	No exitoso	Captura	n	FR %	Indet.	Exitoso	No exitoso	Captura	C/ataque obs.	S/ataque obs.	Total
DEX	3	0.8	1	1	0	1 (1)	9	7.3	5	0	3	1 (1)	2	0	2
DEP-DSA	0	0	0	0	0	0	12	9.7	7	1	2	2 (2)	2	0	2
THA	3	0.8	2	1	0	0	0	0	0	0	0	0	0	0	0
TST	10	2.6	3	3	4	0	18	14.5	7 (1)	2	8	1 (1)	2	0	2
TME	172	44.8	12	21	132	7 (4)	85	68.5	31 (6+1)	10	35	9 (8+2)	21	3+1	25
TCH	15	3.9	5	0	9	1	16	12.9	7	4	5	0	0	0	0
MAC	3	0.8	0	0	3	0	9	7.3	5	1	3	0	0	1	1
PRO	8	2.1	0	0	8	0	7	5.6	2	0	5	0	0	0	0
PAQ	67	17.4	6	0	60	1	10	8.1	5	0	5	0	0	0	0
PCO	48	12.5	9	1	38	0	4	3.2	1	0	3	0	0	0	0
DCA	2	0.5	0	0	2	0	0	0	0	0	0	0	0	0	0
PUG	50	13	16	0	34	0	1	0.8	0	0	1	0	0	0	0
PIN	2	0.5	0	0	2	0	0	0	0	0	0	0	0	0	0
CHA	1	0.3	0	0	1	0	0	0	0	0	0	0	0	0	0
Totales	384		54	27	293	10 (5)	171		70 (7+1)	18	70	13 (12+2)	27	5	32

* The codes of the species are shown in Table 2. The others are THA = *Thalassarche melanophrys* and/or *T. chlororhynchos*, PRO *Procellaria aequinoctialis* and/or *P. conspicillata* and DEP-DSA *Diomedea epomophora* and *D. sanfordi* combined.

Table 3. Sex and age composition of bird bycatch (indeterminate in brackets). Species codes are given in Table 1.

Species code	n	Males/Females	Immature/Adult
TME	25	11/7 (7)	25/0 (0)
DEX	2	0/1 (1)	1/1 (0)
DEP	2	0/1 (1)	1/0 (1)
TST	2	1/1 (0)	2/0 (0)
MHA	1	0/0 (1)	1/0 (0)
Total	32	12/10 (10)	30/1 (1)

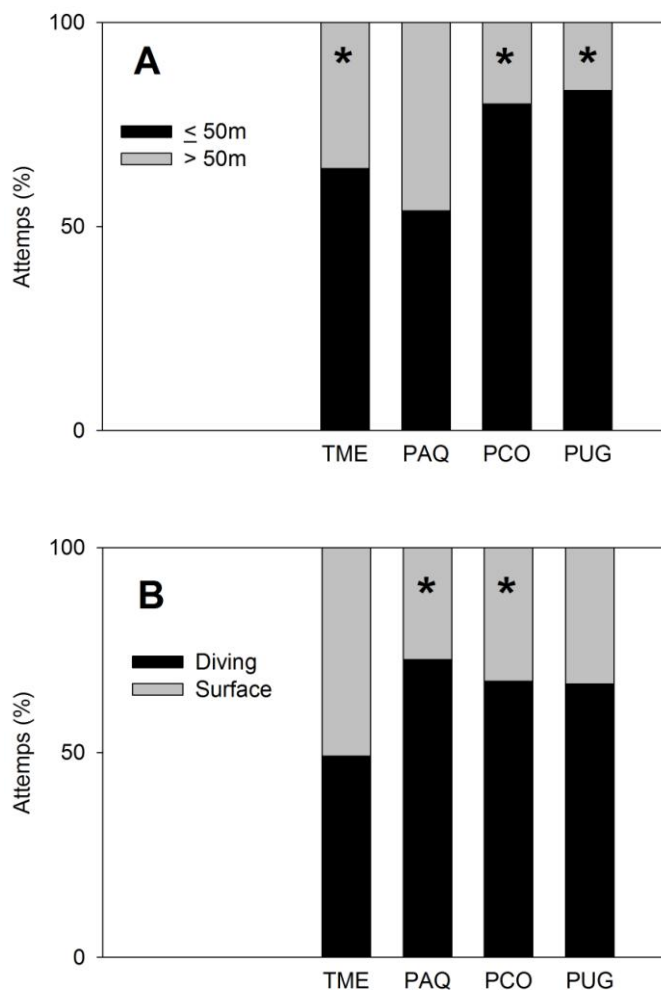


Figure 1. Classification of the primary attacks on bait carried out by the four main species *T. melanophrys* (TME), *P. aequinoctialis* (PAQ), *P. conspicillata* (PCO) and *P. gravis* (PUG). A) Distances at which the attacks were initiated (i.e. $\leq 50\text{m}$ and $> 50\text{m}$). TME n=120, PAQ n=52, PCO n=45, PUG n=42. B) Form in which attacks were initiated (i.e. diving or from the surface). TME n=159, PAQ n=66, PCO n=46, PUG n=27. An asterisk denotes when the χ^2 test showed a significant difference ($p < 0.01$).